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Highlights of Sandia's Photovoltaics Program

Sandia National Laboratories

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Please visit the Web site for Sandia's Renewable Energy Program in Mexico:
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This issue features Sandia's on-going program in Mexico to field photovoltaic and other renewable energy systems in a way that will sustain their use in the future. Sponsored by the Department of Energy (DOE), Sandia began work in Mexico in the early 1990s, initially to explore and strengthen opportunities for the U.S. renewables industry in Mexico. Finding that the climate in Mexico was favorable, the department initiated the Mexico program. In late 1992, the Mexico office of the U.S. Agency for International Development (USAID) joined the DOE in the on-going project because their goals are synergistic; while USAID promotes environmentally sound economic and social development in Mexico, the DOE supports provision of technical assistance and involvement of U.S. industry. Since the inception of the program, more than 100 kilowatts of renewable energy systems—virtually all of them involving U.S. suppliers in partnership with Mexican industry—have been installed in Mexico and have formed the foundation for much replication. Mexico represents an attractive market for the U.S. renewable energy industry, because more than 5 million Mexicans in 88,000 villages do not have access to grid-supplied electricity and more than 100,000 rural communities are in need of potable water. In addition, at least 600,000 ranches need water for livestock and/or irrigation. If these requirements were supplied by a reasonable mix of grid extension and renewable-energy systems, these markets for renewables would total more than one billion dollars.

The Renewable Energy Program in Mexico

Focus of the Program

The goals of the Mexico Renewable Energy Program are to promote use of renewable energy systems, enhance economic and social development in Mexico, create new business opportunities for U.S. industry, and offset greenhouse gas emissions. The original concept was, and still is, focused on rural, off-grid, productive-use applications of renewable energy, particularly photovoltaics and small wind, with some interest in small hydropower and solar thermal systems. Productive-use applications are those that provide an economic or social benefit to the user of the technology, such as water pumping for agricultural use or lighting for an ecotourism facility. Because of the income they provide, productive-use applications provide a built-in means for paying for a renewable energy system. This focus on productive uses distinguishes the Sandia program from other major efforts to introduce photovoltaics into Mexico. For instance, the Mexican government, in partnership with the national utility, initiated a program in the early 1990s to provide electricity using photovoltaic systems primarily for lighting and other uses, such as radios and possibly televisions, in remote areas of the country where grid extension is too costly or unfeasible.* To date, some 1,250 rural communities have been electrified, with as many as 40,000 small solar systems having been installed in Mexico (at the time the article was written). These systems are intended for domestic use, and are not specifically focused on increasing economic productivity.

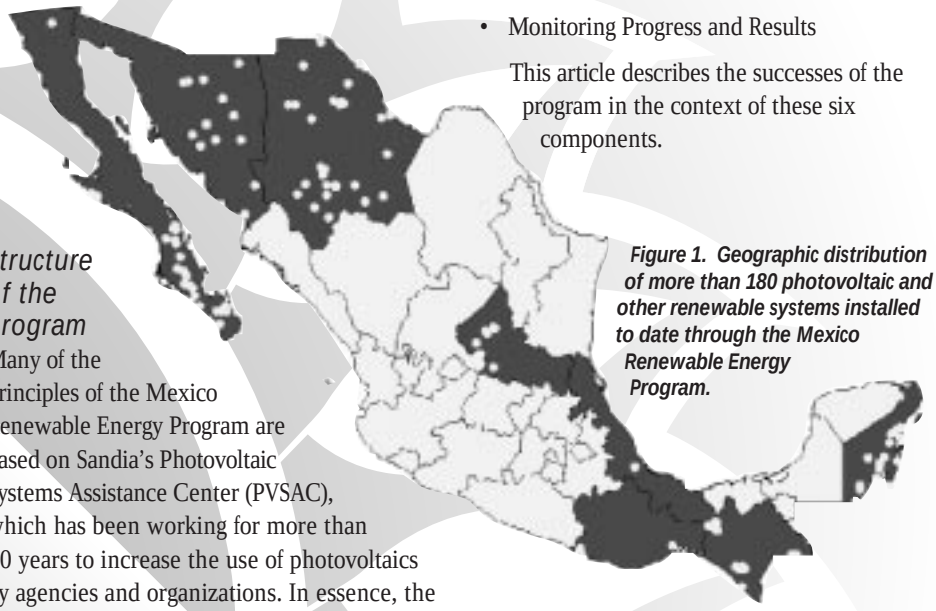

Figure 1. Geographic distribution of more than 180 photovoltaic and other renewable systems installed to date through the Mexico Renewable Energy Program.

Structure of the program

Many of the principles of the Mexico Renewable Energy Program are based on Sandia's Photovoltaic Systems Assistance Center (PVSAC), which has been working for more than 10 years to increase the use of photovoltaics by agencies and organizations. In essence, the philosophy of the PVSAC advocates partnering with established organizations, working within established and funded programs, developing in-house champions in the user organization for projects, and providing technical assistance, training, and hands-on experience to build institutional capacity to use the technology. The PVSAC is careful not to do one-of-a-kind applications, technical demonstration projects, or projects that are not economically, financially, and institutionally viable and technically feasible because of its overarching concern that the projects be replicable.

Sandia's Mexico program models its work on six basic tenets:

- Partnerships
- Capacity Building
- Technical Assistance
- Pilot Project Implementation
- Replication
- Monitoring Progress and Results

This article describes the successes of the program in the context of these six components.

*The government effort is described in "Beyond the Grid: Photovoltaic electrification in Rural Mexico," *Progress in Photovoltaics: Research and Applications* 6, 379-395 (1998)

Program Results to Date

More than 180 pilot renewable energy systems have been installed under Sandia's Mexico program using this model, and they represent more than 100 kilowatts of power, providing services for more than 15,000 rural Mexicans in 9 states. Their geographic distribution is shown in Figure 1(previous page). These systems were chosen to have high visibility and high impact; for instance, they are being used in communal ranches, villages, and bio-diversity reserves where many people will directly benefit from their use and many others will be able to observe these benefits.

Figure 2 shows the cumulative capacity of projects installed for each fiscal year that the program has been in existence. The trend in the graph shows that the rate of implementation has been increasing steadily over the years, and is based primarily on increased familiarity with photovoltaic and other technologies on the part of partners, local suppliers, and end users.

All of these renewable energy systems were installed through partnerships with in-country organizations and help to meet the various needs of these partners. Applications include water pumping for livestock and communities; facilities power for research stations, ranger stations, and ecotourism hotels; and communications systems.

Figure 3 shows the distribution of applications and technologies as applied to installations through the program. As can be seen in Figure 3, the majority of the systems and capacity installed through the program use photovoltaic technology.

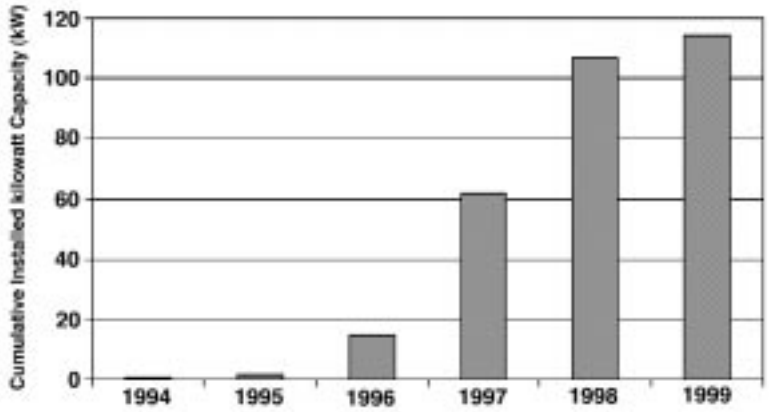

Figure 2. Cumulative capacity of pilot projects installed through the Mexico Renewable Energy Program shown by fiscal year, that is, FY94 runs from 1 Oct. 93 to 30 Sept. 94. The 1999 data reflect only the first quarter of that fiscal year.

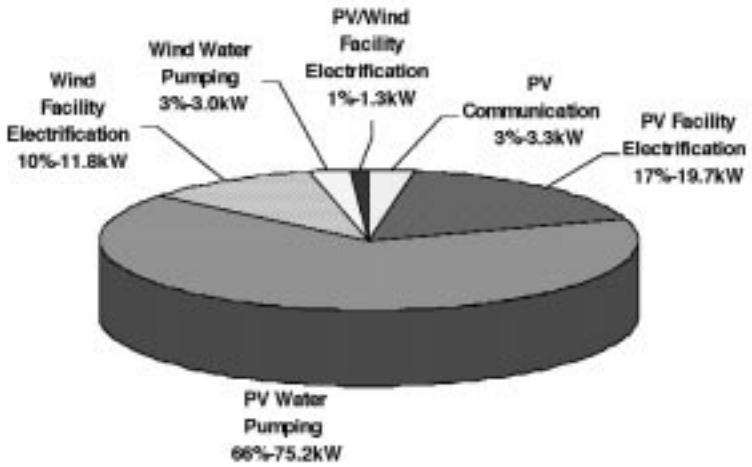

Figure 3. Distribution of applications and technologies by kilowatt capacity of systems installed through the Mexico Renewable Energy Program.

How the program achieved these results using the tenets of the model

Partnerships: Many partnerships have been formed through this program to address the diverse cultural, technical, social, and institutional issues that Sandia has faced in working to meet program goals. The program implementation team itself is composed of several organizations with complementary strengths. In Mexico, partnerships have been formed with several organizations that already have experience with renewable energy technologies and others that had none.

The program's greatest results have come from project implementation activities with rural development and conservation organizations who were new to renewables when the program began.

A multi-institutional implementation team has been formed, with the National Renewable Energy Laboratory (NREL) partnering on several key aspects of the program, such as wind technical assistance and resource assessment. Other members of the team include Southwest Technology Development Institute, Winrock International, Enersol Associates, and Ecoturismo & Nuevas Tecnologías. The combination of these and other organizations brings a diverse set of talents to the program team.

Several partnerships have been developed with institutions in Mexico that are already involved with renewable energy on various levels. As part of the U.S./Mexico Bi-National Agreement, Sandia collaborates with the Mexican Commission for Energy Savings on the development of tools and programs to increase renewable energy acceptance in Mexico. Sandia has also formed agreements with the National Solar Energy Association and the Center for Energy Research of the National Autonomous University. Collaborations with the Federal Electricity Commission and the Mexican Foundation for Rural Development are also underway. These partnerships form the foundation of the program's successes.

Approximately 120 of the systems represented in Figures 1-3 were installed in partnership with an agricultural development organization named Fideicomiso de Riesgo Compartido (FIRCO), an agency under the Mexican Secretary of Agriculture. Through its offices in each Mexican state, FIRCO engineers and technicians work with agricultural producers, such as ranchers, to improve and modernize their techniques, thus increasing their productivity. For example, a FIRCO engineer in the state of Sonora might assist a small rancher in arranging to buy a system to pump, store, and deliver water to his cattle, increasing the amount of water available and usable land on his ranch. Before the development of FIRCO's partnership with Sandia, all such projects included gasoline or diesel-powered pumps. Now, however, FIRCO personnel are encouraging ranchers to utilize renewable energy technologies when feasible and are overseeing the installation of renewable energy systems.

In the state of Chihuahua, more than a dozen development organizations, academic institutions, and municipal governments have formed the Renewable Energy Working Group. Through its partnership with Sandia, this group has overseen the installation of more than 40 water pumping systems for ranching and community water supply. The group is now beginning to implement an innovative financing program within the state specifically for renewable energy technologies that will be accessible for both productive use and home lighting applications. Based on these successes, the working group concept is being encouraged in other states throughout the country.

Another important set of partnerships involves working with organizations devoted to conservation of natural resources and sustainable development in communities located near protected natural areas to incorporate the use of renewable energy in these activities (see Case Study on the Chajul Biological Research Station).

Capacity Building: Sandia's Mexico team has placed great emphasis on assisting partners in building the capacity necessary to independently evaluate and develop projects by offering formal training workshops that often include hands-on installation experience, focused field activities, and in-depth reviews of suppliers' quotes for proposed systems. More than 1,600 people have been trained in various aspects of implementing renewable energy projects, including technical design, installation and acceptance tests, and related issues such as proposal writing and development of financing programs and policies. Engineers, technicians, suppliers, and decision-makers in 90 institutions in 14 Mexican states have received this training and have utilized their resulting capabilities to develop program activities and projects in these states.

Technical Assistance: Sandia and NREL provide technical assistance to program partners in a variety of forms. Working with partners, Sandia has assisted the development of technical specifications for installed systems and has also worked with local suppliers to ensure that they understand what is required to meet these specifications. NREL has conducted extensive studies of solar and wind resources in Mexico and has developed resource maps of the country and specific regions. These maps are valuable tools for partner organizations and systems suppliers as they work to determine the most feasible regions for renewable energy technologies. These and other forms of technical assistance are provided as part of the capacity building process. In addition to assisting program partners in making informed decisions about the appropriate use of renewable energy technologies, this work provides in-country access to specialized expertise.

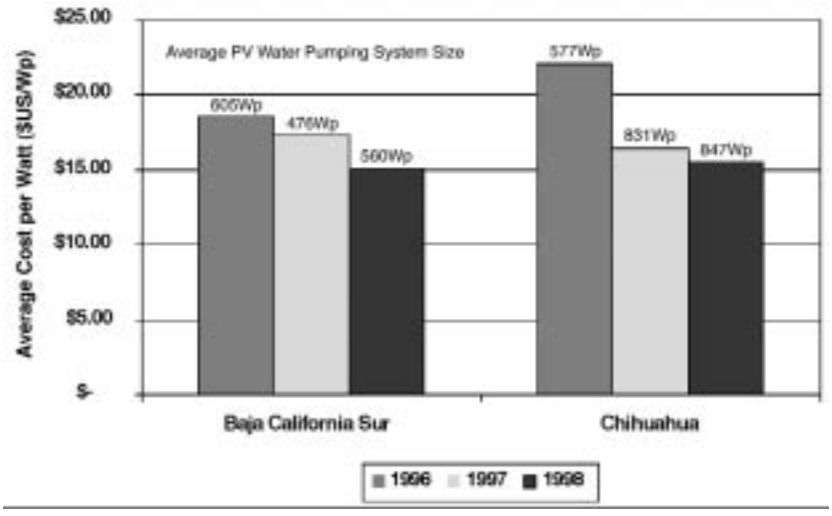

Figure 4. Average cost per watt of water pumping systems installed, broken down by fiscal year. Data are shown for the states of Baja California Sur and Chihuahua.

Pilot Project Implementation: Implementing pilot projects is a way to realize the use of renewable energy systems. After fielding about 180 pilot projects, Sandia and its partners are building the foundations of growing, sustainable markets. Local suppliers have a better technical understanding of the integration of photovoltaic systems and have learned that with adequate planning, little cost is required to maintain installed systems. As a result of this and an increased demand, prices to end users have been declining in areas where the program is well established, as is shown in Figure 4. This can be seen in the cases of both Baja California Sur and Chihuahua, where the program has been active for at least three years, and, more important, has gone through several cycles of project development and procurement.

One way Sandia helps end users overcome the perceived risks associated with the introduction of new technologies is to share the cost of pilot system installations. Photovoltaic and wind systems involve considerably higher initial investments than conventional gasoline or diesel-powered systems. By using USAID funds to share these initial investments, project engineers and end users are more willing to assess the value of these new technologies. As customers gain more experience, and installed systems gain visibility, the perceived risk reduces over time, as does the Sandia contribution. Figure 5 illustrates this trend. In

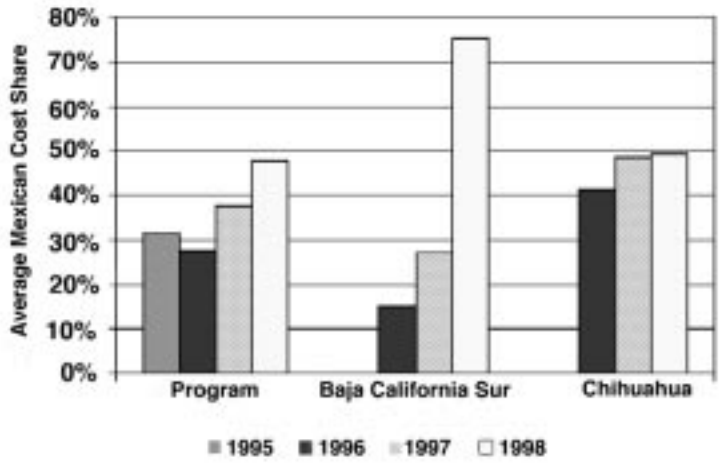

Figure 5. Average in-country cost-share for installed photovoltaic water pumping systems, shown by fiscal year.

the cases of Baja California Sur and Chihuahua, increased consumer confidence based on early installations has led to a greater willingness to invest in photovoltaic systems. The in-country cost share trend shown for Baja Sur reflects the incorporation of a major national development program, whereas the Chihuahua trend reflects willingness on the part of the end users to pay a greater percentage of the system costs. The data shown for the overall program are less conclusive because they blend the results from several distinct geographic regions in different stages of program implementation.

Sandia helps to share the costs of these projects through contractual arrangements with its partners, but the partners purchase the equipment from the suppliers. Thus, systems installed through the program are truly pilot projects, and after Sandia's involvement diminishes, partners will have the fully-developed capacity to continue to purchase renewable energy systems.

The value of this program to the U.S. renewable energy industry is in the increased access to Mexican markets through local system suppliers. Therefore, the importance of including U.S. and Mexican industries in all aspects of the program cannot be overemphasized. On a local level, sustainability and growth of markets can only be ensured if a strong supply infrastructure exists and if installed systems function reliably over time. Therefore, Sandia works closely with local suppliers to help them strengthen their ability to deliver high-quality systems at reasonable costs to end users. As part of this process, Sandia works to facilitate the formation of partnerships between U.S. and Mexican suppliers. To date, more than 40 Mexican and U.S. companies have participated in the program, through attendance and presentations at training courses, installation of pilot systems, and the development of their own training programs. Several U.S./Mexican supplier partnerships have been formed, resulting in greater customer satisfaction and strong, growing local markets for photovoltaic systems (see Case Study on Water Pumping).

Location	Program Sponsored Installations		Non-program Sponsored Installations	
	# of systems	kW	# of systems	kW
El Ocote Reserve, Chiapas	10.0	3.5	141.0	8.0
Sonora System Supplier	13.0	5.0	35.0	7.0
FIRCO Baja California	1.0	0.1	45.0	14.0
Chihuahuahua System Supplier	4.0	6.3	76.0	20.0

Table 1. Examples of spin-off project replication, where program-sponsored installations have led to non-program sponsored installations with the same organizations or in the same regions.

Replication: Project replication, or growing sustainable markets, is the program's ultimate measure of success or failure and can occur in a number of ways. As partner institutions gain familiarity with the use of renewable energy technologies, they begin to implement new projects on their own. This generally occurs within a specific region first and then spreads to new regions. Through these activities, other related institutions become familiar with the merits of renewables and initiate projects as well. For example, in Chiapas, the success of projects that were installed with partner conservation organizations led to nearby municipal governments electing to use community funds to purchase photovoltaic systems for their constituents' houses. The potential for this type of replication can be huge, given that budgets for development organizations can be in the millions, even billions of dollars. Private-sector spin-off replication occurs as a result of successful pilot projects. For replication to be substantial, several factors must be adequately addressed: the local population must know the technology and what it can provide; quality products and services must be available locally; and the ability to pay for the technology must exist. For the latter reason, access to applicable financing mechanisms is key.

In efforts to assess program effectiveness, the Sandia team has been collecting data related to replication based on pilot projects. Table 1 shows four specific examples of replicated projects that fall into the categories mentioned above.

These data are preliminary and Sandia is focusing more effort on obtaining this type of information from partners, end users, and suppliers in the future. However, based on solid examples of project replication, the data serve to demonstrate that the Mexico Renewable Energy Program is beginning to create the intended effects.

Perhaps the greatest example of program success to date is a proposal that FIRCO is developing for the World Bank and the Global Environment Facility, through which FIRCO intends to dramatically increase the rate of project implementation achieved in partnership with Sandia. Whereas FIRCO and Sandia succeeded in installing approximately 120 photovoltaic water pumping systems in the last 5 years, FIRCO is developing a program that will result in as many as 5,000 photovoltaic and wind systems installed nationwide over the next 5 years.

Monitoring: To evaluate the effectiveness of a program, continuous monitoring of results is necessary. Monitoring activities must be designed into the program at its inception and should focus on several issues, including the technical, social, economic, and environmental impacts of the appropriate use of the technologies and applications. The majority of monitoring data come from interviews with partner agencies, suppliers, and end users, and from visits to specific sample sites. For some complex or novel systems, performance monitoring equipment is installed and analytical reports are developed.

For this program, an extensive database is being maintained at Southwest Technology Development Institute, and all applicable project and program information is being collected from field personnel. Maintaining this database allows program personnel to conduct analyses and make necessary adjustments along the way. As the program continues its transition from direct implementation of pilot projects to further replication and institutionalization of partner organizations, these monitoring efforts will continually grow in importance. For this reason, monitoring activities under the program are being redefined to address new issues.

Sandia is collecting and will continue to collect data to determine whether maintenance is being performed, and on the quality and types of maintenance, as well as on customer satisfaction with the systems. This information comes from program partners, vendors, and customer surveys. Because the program is built on the strength of continued partnerships, Sandia is in a position to collect valuable data regarding the installed systems. Preliminary indications are that appropriate maintenance is being performed when needed and that end users are extremely pleased with their systems. The data and analysis are preliminary and will be a major focus of program activities in the future. These preliminary results, however, provide indications of expected program results and also illustrate the types of data that are being collected.

Lessons learned in the Mexico Program

Implementing this program has provided a wealth of information about what works and what doesn't. The key lessons learned follow; the first two are really Photovoltaic Systems Assistance Center philosophies that were reconfirmed.

- Solid partnerships are essential: A program such as this one depends for its success on working with in-country organizations and with industry, in this case, on both sides of the border. In addition, the program team itself, which is composed of members from different organizations, must function well together. It is important to choose partners carefully.
- The program must be focused to make the most of available resources: In other words, do one thing well rather than many things poorly. When successes are realized in this focused manner, new opportunities can be pursued later. In general, many more options for partnering and tapping into opportunities exist than resources can support; therefore, focus, limit, and succeed in a few locations, then expand. Similarly, emphasize projects that have a high probability of replication. One-of-a-kind efforts can quickly tap valuable resources, while offering little in the way of long-term returns.
- Development issues must be integrated with, even given precedence over, pushing technology or environmental issues: The initial impetus for the program was to create new opportunities for U.S. business and to offset greenhouse gas emissions. However, it did not take long for the program to realize that if it were going to succeed and have any lasting effects, the work had to be done from a development perspective first.
- Pilot projects should be used as a tool, not an end: Pilot projects should be installed to establish growing and sustainable markets, not to be able to point to the number of installations accomplished during the project. Their primary value is as tools for training and building the capacity of implementing organizations, business, and the user community. The real measure of their success is in the replication of projects that results from the program.
- Provisions should be made to improve the capacity of local business: The success of this program depends greatly on providing training and technical assistance to local suppliers of renewable energy systems. The improved capacity of local suppliers in Mexico has led to greater consumer confidence and to better quality products.
- Contracting mismatches must be addressed properly: Contracting and legal staff must be involved early in a program such as this one—especially involving a foreign government—to avoid delays and misunderstandings as the program progresses. The differences in requirements for procurements and sharing of funds between the U.S. and a foreign government can be substantial.
- Measuring replication requires a concerted effort and significant resources: The Mexico program has a monitoring process in place, but it does not yet do an adequate job of tracking replication. Adequate resources must be allocated to ensure monitoring of replication if the true impact of the program is to be known.
- Multi-year planning and budgeting are essential: Government-funded programs generally impose a one-year cycle on which to base planning and budgeting. This program has greatly benefited from multi-year funding, mainly because the results of a program such as this one tend to show up toward the end of several years' effort.

Work still to be done in Mexico

There are several issues to be addressed as the Sandia team continues to work with its Mexican partners on the broader acceptance of renewable energy technologies in Mexico. One of the most critical areas still needing attention is facilitation of financing mechanisms for renewable energy systems through banks or non-government organizations. The Mexican financial crisis that began in late 1994 with the devaluation of the peso and interest rates in excess of 70% effectively derailed activities in this area. By late 1997, interest rates had settled to around 20% for rural loans, but the Asian and Russian financial crises in 1998 provoked an increase in Mexican interest rates to around 35-40%. In addition, more program monitoring is desirable, in particular, data regarding renewable energy business development, as is data on spin-off replications (market growth), analysis of customer satisfaction, and information on the effect renewable energy systems are having on local economic development via the productive-use applications. Increasing the renewable energy industry's involvement in the program is another area needing attention. Also, given the estimated size of the markets in Mexico, the program would like to get more U.S. companies interested in Mexico. If FIRCO's proposed replication program is initiated this year, all of these issues will require increased attention.

Although the work under this program has so far emphasized photovoltaics, the basic program model is applicable to other technologies and other locations. With technical help from the National Renewable Energy Laboratory, several small wind systems have been installed in Mexico, in efforts to lay the foundations of sustainable wind markets. USAID is adapting this model for its energy efficiency programs. Also, Sandia is working with its partners to assess and demonstrate the applicability of the Mexico program model in other international settings, such as in Central or South America.

(For more information about Sandia's Renewable Energy Program in Mexico, contact Charlie Hanley, cjhanle@sandia.gov)

Case Study: Chajul Biological Research Station, Montes Azules Integrated Biosphere Reserve, Chiapas, Mexico

Deep in the jungle of Southeastern Chiapas, Mexico, is the Chajul Biological Research Station (Figure 6), made up of remote research and multi-use facilities where scientific studies are conducted on a vast diversity of wildlife and plant species. The station is located about 200 meters from the southern border of the Montes Azules Integrated Biosphere Reserve. The scientists and other personnel who visit the station for extended periods play a significant role in protecting the fragile ecosystems within the reserve from the pressures of encroaching human development.

Power was needed for full electrical service for the 20 permanent personnel on site and for the more than 700 people who visit the station each year. Specific loads included ceiling and floor fans to reduce the oppressive heat, a freezer to preserve food for the staff and visitors (and to reduce the frequency of food transport from off-site), a water-purification system, computers, television, radio, indoor and outdoor lights, and scientific equipment. A water pump will probably be installed in the future. The remoteness of the site and its ecological fragility made line extension not only expensive, but dangerous to the rainforest's ecosystem. The station is run by an international organization named Conservation International. Sandia developed a partnership with the organization to help use photovoltaics to supply the station's energy needs.

This was a pilot project for Conservation International; it was the first of its kind both in Mexico and within the organization's world-wide activities. Although its staff in Mexico had had some prior experience with photovoltaics, they had not received associated training and technical assistance to ensure that the systems would continue to perform and provide the services expected.

With personnel from Conservation International based in Chiapas, Sandia helped establish the priorities of the project. The outcome of the process was a decision to use an 11.4-kW photovoltaic system with propane back-up at the Chajul research station, making it the largest photovoltaic system installed under Sandia's Mexico Renewable Energy Program to date. Sandia team members provided ongoing support throughout the project's development phases to ensure that the Chajul system was appropriately sized, complied with recommended safety practices, was of high quality and technically sound given the field conditions, and that Chajul

Figure 6. Chajul Biological Research Station in Chiapas.

personnel were confident about operating and maintaining the system. Technical assistance was also transmitted by occasional hands-on training courses and systems acceptance testing with Sandia team members. The vendor, Condumex/IEM, provided formal maintenance training of field staff and a complete operations and maintenance manual when the installation was complete.

All of the effort that went into partnering, capacity building, and technical assistance paid off in a very significant and unexpected fashion when Hurricane Mitch visited the area shortly after the photovoltaic system was installed and commissioned. Upon learning that Chajul was in Mitch's path, Conservation International and its local partner organization, Espacios Naturales, went through a series of preplanned actions in preparation for its arrival. The system was shut down and the moveable equipment was stored in safe locations. Even preplanning in the design stages helped; in spite of more than 2 meters of flooding brought on by the hurricane, the batteries had been placed so that they were submerged by only 30 to 50 cm of water. When the flooding subsided, Espacios Naturales hired the installer to return to the site to conduct a thorough investigation before reconnecting the system. Thanks to these precautions, the system is once again fully functional.

Sandia has helped install more than 75 independent photovoltaic and wind systems in and around protected areas in southern Mexico through partnerships with Conservation International, The Nature Conservancy, World Wildlife Fund, and several of their in-country partner organizations. These systems have greatly improved the capacity of these organizations to effectively manage the protected areas of Mexico, and have improved the quality of life for many people living in the marginal areas that border these reserves. As a result, the partner organizations—and the communities near them—are starting to use photovoltaics to meet energy needs in other projects. Sandia and its partners will continue to monitor the impacts of these systems to assess the benefits they provide.

Case Study: Water Pumping for Livestock and Irrigation in Agua Blanca, Baja California Sur

Marcos Alvarez, who owns a small cattle ranch in Agua Blanca, Baja Sur California, Mexico, used to face a hardship every year that cost him many thousands of pesos and the loss of some of his herd. During the hot, dry spring months he would be forced to buy expensive feed for his 39 steers, and his ranch hands would spend extra hours each day ensuring the cattle had sufficient water. Now—thanks to a photovoltaic water pumping system (Figure 7)—he has new grass coming up in the spring (Figure 8), water flows automatically to a drip irrigation system (Figure 9), and he has an emergency supply of food for his cattle: silage made from grass grown on his ranch.

Through its partnership with Sandia, the Mexican organization Fideicomiso de Riesgo Compartido (FIRCO, the Federal Trust for Shared Risk) helped Alvarez with his water problems. In 1998, FIRCO engineers learned of Alvarez's situation, and, based on several years' experience working with Sandia's Mexico Program staff, they were able to assess the suitability of the site for a photovoltaic water-pumping system. When Alvarez agreed to invest in a photovoltaic system to pump water for his cattle and irrigate his fields, the same engineers obtained and reviewed quotes from vendors and assisted in completing the sale of the system. After the system was installed, they conducted an acceptance test before final payment was made to the supplier.

After collaborating with Sandia for three years, FIRCO engineers in Baja Sur California are helping many ranchers grow feed and provide water for their cattle by using photovoltaic systems. This collaboration began with a formal workshop in October 1995—attended by engineers, technicians, decision makers, and vendors—at which attendees gained hands-on experience in installing a photovoltaic water-pumping system. Over the ensuing years, through field work, system design and sizing exercises, and bidding procedures, this capacity building continued, with Sandia providing technical assistance with each activity. Sandia and FIRCO are now partnering in nine states, and as a result, FIRCO is developing the framework for nationwide expansion of such projects. The World Bank and the Global Environment Facility are working with FIRCO to define and help finance this large replication activity.

The Alvarez water-pumping system is an example of part of this larger FIRCO project, in which the organization collaborates with individual rural producers to modernize, update, and increase their productivity through a variety of means, one of which may be installing a renewable energy system. Other assistance the organization gives includes, for example, seeds for new pastures and new equipment, such as tractors and electric fences. Because this is part of a FIRCO effort, communication has been maintained with Alvarez (and with others who installed systems through the Mexico program) to assess the system's technical functioning and also to measure its social, economic, and environmental impacts. Collecting this type of information allows Sandia to conduct several analyses at the program level.

Figure 7. New photovoltaic water pumping system . . .

Figure 8. . . . produces lush spring grass.

Figure 9. Automatic water flow into a drip irrigation system is the result of a photovoltaic water pumping system.

Sandia works closely with suppliers to ensure that they have the necessary technical capabilities to develop, implement, and maintain such systems. Three years ago, the company that supplied this system did not have experience with water pumping systems, nor did it have a strong technical background or training. Through involvement with Sandia's program, the company has established a strong partnership with a U.S. supplier, who provides design assistance and regular technical training to the vendor in Mexico and provides him with components and systems. The partnership has greatly strengthened the competitive capabilities of this local business and has led to many follow-on sales. In fact, sales have doubled during each of the last two years, and 1999 promises to continue this trend.

The Alvarez water-pumping system demonstrates the benefits of photovoltaic technology to other ranchers in the region. Using data from this project, Sandia and FIRCO conducted analyses to illustrate these benefits. In this instance, the ranch has 1,001 hectares, with 25 hectares in buffalo grass. An 800-watt photovoltaic water-pumping system replaced an 8-horsepower gasoline motor pump, which consumed an average of 2,000 liters of fuel per year. The initial costs for the photovoltaic system were approximately twice the amount of the conventional technology. However, because of the higher costs of maintaining and operating the gas pump, a life-cycle cost analysis has shown that after only six years, the photovoltaic system will be a lower cost option. In addition, in the past Alvarez had to personally oversee the operation of his 8-horsepower pump for up to an hour a day. Now, his 800-watt solar water-pumping system provides the same amount of water unattended during the course of the day. This kind of information is valuable to other ranchers who are considering purchasing photovoltaic systems for pumping water.

Sandia creates and distributes a variety of publications on photovoltaic systems and their applications. For a list of these documents, please contact the Photovoltaic Systems Assistance Center:

through e-mail: *pvsac@sandia.gov*

by phone: *505-844-3698*

by FAX: *505-844-6541*

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